OHIO RIVER BASIN PRECIPITATION FREQUENCY STUDY

Update of *Technical Paper No. 40, NWS HYDRO-35* and *Technical Paper No. 49*

Twelfth Progress Report
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Hydrometeorological Design Studies Center
Hydrology Laboratory

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DISCLAIMER

The data and information presented in this report should be considered as preliminary and are provided only to demonstrate current progress on the various technical tasks associated with this project. Values presented herein are NOT intended for any other use beyond the scope of this progress report. Anyone using any data or information presented in this report for any purpose other than for what it was intended does so at their own risk.

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OHIO RIVER BASIN
PRECIPITATION FREQUENCY STUDY

Update of *Technical Paper No. 40, NWS HYDRO-35* and *Technical Paper No. 49*

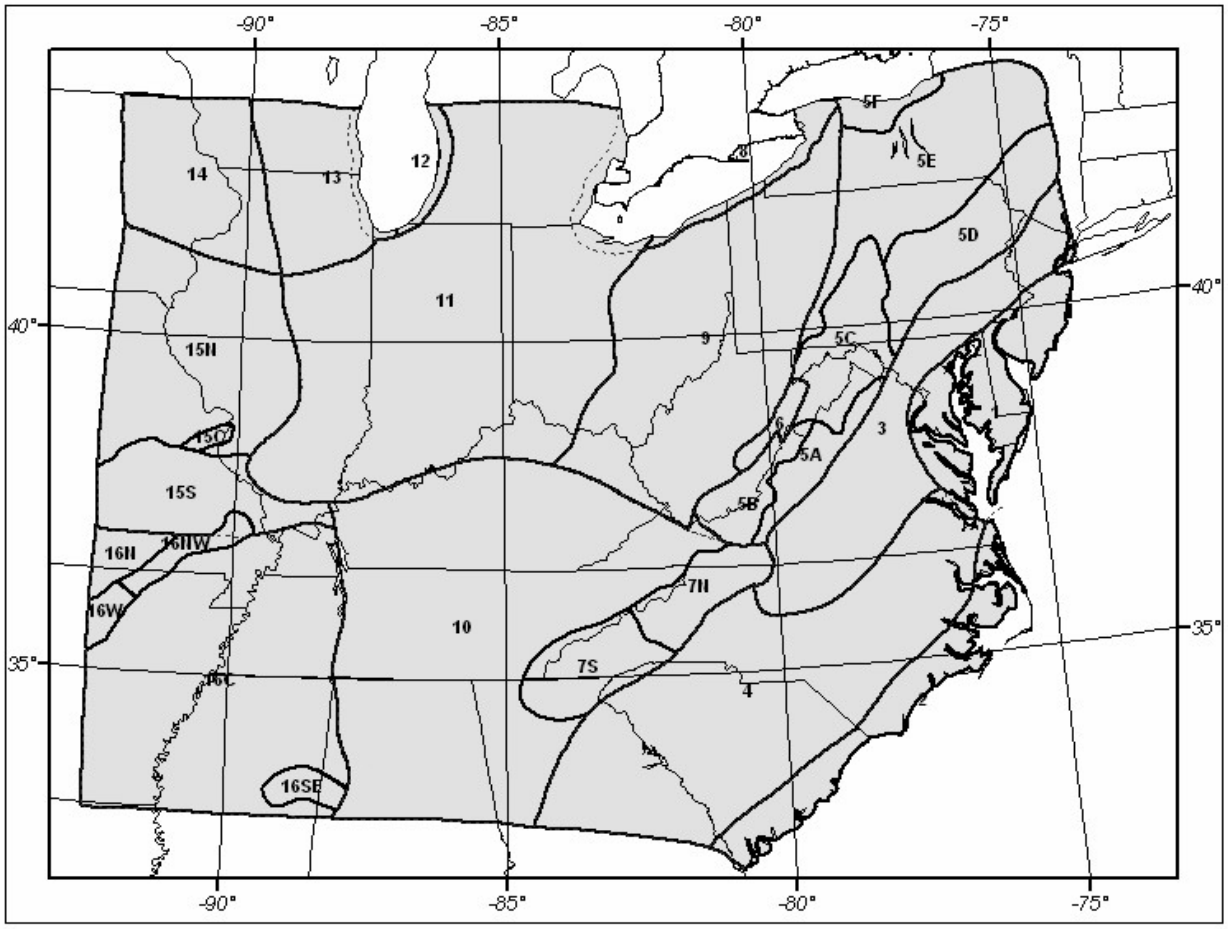
1. Introduction

The Hydrometeorological Design Studies Center (HDSC), Hydrology Laboratory, Office of Hydrologic Development, U.S. National Weather Service is updating its precipitation frequency estimates for the Ohio River Basin and surrounding states. Current precipitation frequency estimates for this area are contained in *Technical Paper No. 40* "Rainfall frequency atlas of the United States for durations from 30 minutes to 24 hours and return periods from 1 to 100 years" (Hershfield 1961), *NWS HYDRO-35* "Five- to 60-minute precipitation frequency for the eastern and central United States" (Frederick et al 1977) and *Technical Paper No. 49* "Two- to ten-day precipitation for return periods of 2 to 100 years in the contiguous United States" (Miller et al 1964). The new study includes collecting data and performing quality control, compiling and formatting datasets for analyses, selecting applicable frequency distributions and fitting techniques, analyzing data, mapping and preparing reports and other documentation.

The study will determine annual all-season precipitation frequencies for durations from 5 minutes to 60 days, for return periods from 2 to 1000 years. The study will review and process all appropriate rainfall data for the study area and use accepted statistical methods. The study results will be published as a Volume of NOAA Atlas 14 on the Internet with the additional ability to download digital files.

The study will produce estimates for 13 states. Parts of nine additional bordering states are included to ensure continuity across state borders. The Susquehanna River and Delaware River Basins are included in the study area. The core and border areas, as well as tentative regions now used in the analysis, are shown in Figure 1.

Figure 1. Updated Ohio River Basin study area and region boundaries.



2. Highlights

Internal consistency software was revised to adjust quantiles through the 24-hour duration for hourly-only stations. Software was developed to adjust quantiles for co-located hourly and daily data, particularly across the 12-hour to 24-hour durations where discontinuities have been observed. Lastly, software has been written to calculate conversion factors from annual maximum series to partial duration series which will be part of the final deliverable. Additional information is provided in Section 4.1, Software Updates.

A region by region examination of heterogeneity results from L-moment analysis is currently underway. Additional information is provided in Section 4.2, L-moment Analysis.

On July 30, 2002 Geoff Bonnin and Tye Parzybok traveled to the Spatial Climate Analysis Service (SCAS) at Oregon State University, Corvallis, Oregon to discuss and obtain the first draft PRISM-interpolated Semiarid mean annual maxima (a.k.a. “index flood”) grids for 1-hour and 24-hour. The successful all-day meeting involved technical discussions about the grids and PRISM. Additional information is provided in Section 4.3, Spatial Interpolation.

In addition to the 12 and 24 hour durations, temporal distributions will be produced for the 4-day duration. Additional information is provided in Section 4.4, Temporal Distribution.

The Semiarid observing site review allowed users to not only review the Semiarid precipitation frequency estimates, but the Precipitation Frequency Data Server (PFDS as well. The PFDS premiered well, and a tremendous amount of valuable input was received and quickly incorporated into the PFDS. Additional information is provided in Section 4.5, Precipitation Frequency Data Server.

Progress towards the development of depth-area-duration (D-A-D) reduction relationships for areas from 10 to 400 square miles continues. The progress includes identification of four additional study areas, completion of quality control on the existing eight study areas, and testing of the initial computer programming. Additional information is provided in Section 4.6, Spatial Relations (Depth Area Duration Study).

HDSC is presenting four papers/posters at the 83rd American Meteorological Society Annual Meeting in February of 2003. Additional information is provided in Section 5, Issues.

3. Status

3.1 Project Task List

The following checklist shows the components of each task and an estimate of the percent completed per task. Past status reports should also be referenced for additional information.

Ohio River Basin study checklist [estimated percent complete]:

Data Collection, Formatting and Quality Control [100%]:
- Multi-day
- Daily
- Hourly
- 15-minute
- N-minute

As data issues may arise in subsequent tasks, quality control is essentially a continuous process.

L-Moment Analysis/Frequency Distribution for 5 min. to 60 days and 2 to 1000 years [75%]:
- Multi-daily
- Daily
- Hourly
- 15-minute
- N-minute

A region by region examination of heterogeneity results from L-moment analysis is currently underway.

Spatial Interpolation [5%]
- Create mean annual maximum (a.k.a. "index flood") grids with PRISM for all durations from 60-minute to 60-days
- Apply a precipitation frequency map derivation procedure, known as the cascade residual add-back (CRAB) procedure to create a total of 162 grids. The same procedure will be used to create 162 upper and 162 lower bound precipitation frequency grids (see Section 4.3, Spatial Interpolation).
- Apply study-wide conversion factor to the 1-hour precipitation frequency grids to calculate the n-minute (5-, 10-, 15-, and 30-minute) grids.

Peer Reviews [0%]:
- External peer review of point precipitation frequency estimates
- External peer review of spatially interpolated grids

Data Trend Analysis [0%]

- Analyze linear trends in annual maxima and variance over time
- Analyze shift in means of annual maxima between two time periods (i.e., test the equality of 2 population distribution means)

Temporal Distributions of Extreme Rainfall [75%]

- Assemble hourly data by quartile of greatest precipitation amount and convert to cumulative rainfall amounts for each region
- Sort, average and plot time distributions of hourly maximum and median events by storm area, quartile and duration

Deliverables [40%]

- Prepare data and documentation for web delivery

The PFDS premiered well during the initial Semiarid review, and a tremendous amount of valuable input was received and quickly incorporated into the Precipitation Frequency Data Server (PFDS).

Additional Work:

Spatial Relations (Depth Area Duration Study) [40%]

- Obtain hourly data from dense-area reporting networks
- QC and format data from dense networks
- Compute maximum and average annual areal depth for each duration from stations from each network
- Compute maximum to average depth ratio for all durations and networks and plot
- Prepare curves of best fit (depth area curves) for each duration and network

Depth Area Duration (DAD) reductions for areas from 10 to 400 square miles are being updated for the entire United States and will be presented in separate volume of NOAA Atlas 14.

4. Progress in this Reporting Period

4.1 Software Updates

Internal consistency software was revised to adjust quantiles through the 48-hour duration for hourly-only stations. Cases where a shorter duration has an estimate that is higher than the next longer duration (e.g., 2-hr = 1.9 and 3-hr = 1.5) are mitigated with a practical adjustment using ratios based on the 1-hour duration.

Software was developed to adjust quantiles of co-located hourly and daily stations, particularly across the 12-hour to 24-hour durations. This adjustment assumes that the daily 24-hour quantiles are true because they are based on our most consistent values and generally have longer record lengths. The method preserves the hourly distribution for 60-minute through 12-hour quantiles at a given hourly station. It then adjusts the quantiles using ratios based on means and regional growth factors (RGFs); these are the primary parameters in calculating quantile estimates and thus are the major contributors to any observed disconnect between the hourly 12-hour and 24-hour estimates. The software was modified to run on all co-located stations on a region-by-region basis.

Software has been written to calculate conversion factors from annual maximum series to partial duration series. This software will be tested and run for all durations and return frequencies. The AMS to PDS ratios will be averaged for each region and reported in the final deliverable.

4.2 L-moment Analysis

An initial run of the L-moment software had been completed for all daily and hourly durations for all regions. The results indicated that most regions are statistically homogeneous. A homogenous region satisfies statistical tests of the hypothesis that the shape of the probability distribution is the same at each observing site in the region. A region by region examination of heterogeneity results from L-moment analysis is currently underway.

Since 24-hour precipitation frequency estimates are the most stable and abundant and have been through excruciating quality controlled, the original 16 regions of the study have been subdivided into 28 regions thus far based on L-moment analysis of 24-hour data. During the subdivision process, heterogeneous regions are re-grouped into homogeneous regions based on climatology, topography, real data checks and statistical results. In the real data check, large discrepancies between 100-yr estimate and maximum observed rainfall are carefully examined. The Generalized Extreme Value (GEV) distribution has been determined to be the best-fit distribution for the study area for 24-hour values.

4.3 Spatial Interpolation

On July 30, 2002 Geoff Bonnin and Tye Parzybok traveled to the Spatial Climate Analysis Service (SCAS) at Oregon State University, Corvallis, Oregon to discuss and obtain the first draft PRISM-interpolated Semiarid mean annual maxima (a.k.a. "index flood") grids for 1-hour and 24-hour. The successful all-day meeting covered the following items:

- To better understand how PRISM (Parameter-elevation Regressions on Independent Slopes Model) spatially interpolates mean annual maxima values to grids
- Assessment of hard-copy maps (contoured) of the draft grids 1-hour and 24-hour "index flood"
- The evaluation of suspect data points and their influence on the grid results
- Inspection of model performance in difficult areas (e.g. transition between orographically-forced extreme regime in central New Mexico to a regime of more synoptically-forced events in eastern New Mexico)
- Differences between the NOAA Atlas 2 2-year 1-hour and 24-hour maps

It was concluded at the meeting that PRISM was doing an excellent job and was properly parameterized to spatially interpolate point index flood values.

The draft "index flood" grids allowed HDSC to fully test the precipitation frequency map derivation procedure, known as the cascade residual add-back (CRAB) procedure. CRAB is a derivation process that utilizes the strong, linear relationship between a particular duration and frequency (e.g. 50-year 24-hour) and the next higher frequency (e.g. 100-year 24-hour). In fact, this relationship within a region is a constant obtainable from the regional growth factors. With the CRAB procedure however, a global (all-region) relationship is developed based on actual observing-site data, then the linear relationship is applied to the preceding grid (i.e. 50-year 24-hour) to establish a first guess 100-year 24-hour grid. Knowing regional differences occur, residuals (actual minus observed) are calculated for each observing-site and then normalized (divided by) by the preceding estimate (50-year 24-hour). These (point) normalized residuals are then spatially interpolated to a grid. The resultant grid is then denormalized by multiplying it by the preceding grid to obtain a grid of actual residuals, in inches. The last step is to simply add the residual grid to the first guess grid to arrive at the final 100-year 24-hour grid. The process, as the term cascade implies, utilizes a previously derived grid to derive the next grid. So the same process is followed for deriving the 200-year 24-hour grid, but instead of the 50-year 24-hour grid being used as the predictor, the new 100-year 24-hour grid is used.

Ohio data preparation is taking place and in October, after the observing-site review, the data will be provided to the SCAS for gridding.

4.4 Temporal Distribution

To better correspond with precipitation frequency durations that will be computed, a 4-day temporal distribution will be presented instead of a 3-day. Temporal distributions for 12 and 24 hour storms have already been computed.

4.5 Precipitation Frequency Data Server

The Semiarid observing site review allowed users to not only review the Semiarid precipitation frequency estimates, but the Precipitation Frequency Data Server (PFDS) as well. The PFDS held up well during its first debut, and a tremendous amount of valuable input was received and quickly incorporated into the PFDS.

Such changes and bug fixes include, but are not limited to: fixed problem of data truncation at 100 inches, fixed the “Download table as text” function, added new Depth-Duration Frequency (DDF) graph, changed the title of the x- and y-axis, added more “Submit” buttons to alleviate confusion on getting to the output page, modified screen width so that it fits on one screen, limited the list of stations in the pull-down menu to only those stations in the selected state.

To provide users a complete perspective of precipitation frequency estimates, a new graph is now part of the precipitation frequency output page. An example of the new graph is shown below in Figure 2.

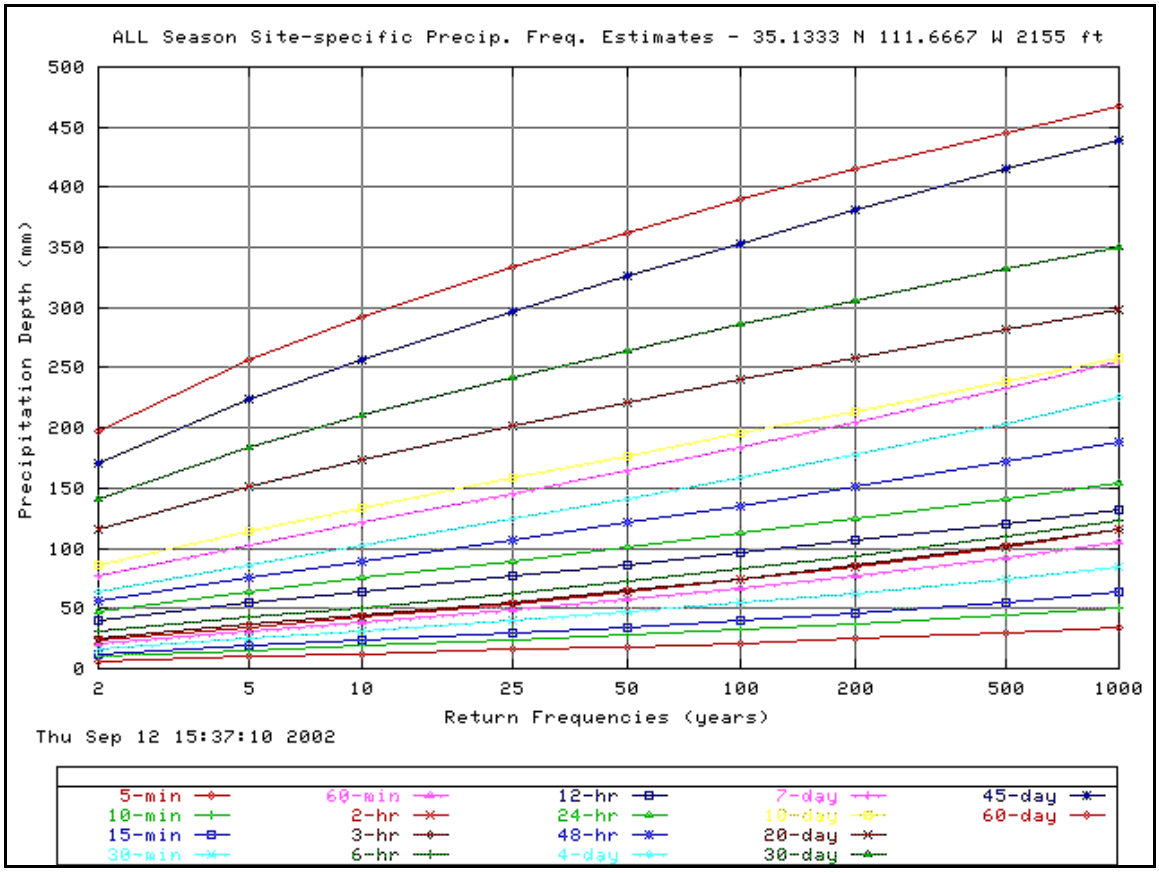


Figure 2. Sample Depth-Duration Frequency Graph.

4.6 Spatial Relations (Depth Area Duration Study)

Progress towards the development of depth-area-duration (D-A-D) reduction relationships for areas from 10 to 400 square miles continues. Four additional study areas (three in California and one in Arizona) have been identified and will likely be included in the D-A-D study. Quality control on the existing eight study areas has been completed. A new study area in the Middle Atlantic area may also be used. The initial computer programming has been written and successfully tested on two study areas. The secondary D-A-D programming continues and will be completed early in the next quarter. Upon completion, the final D-A-D reduction relationships will be available for use in basins throughout the United States. Data has been collected and prepared as shown in Table 1.

Table 1. Dense Area Rain Gauge Networks in D.A.D. Study.

Depth Area Duration Study Areas	**Data Extraction & Re-Formatting**
Walnut Gulch, AZ	X
Reynolds Creek, ID	X
Tifton, GA	X
Hastings, NE	X
Alamogordo Creek, NM	X
Safford, AZ	X
Santa Rita, AZ	X
Cochocton, OH	X
Danville, VT	X
Chicago, IL (NCDC stations)	X
Riverside, CA	X
Maricopa County, AZ	X
Ventura County, CA	
Santa Clara County, CA	
Santa Barbara County, CA	

5. Issues

5.1 AMS Conference

HDSC is presenting four papers/posters at the 83rd American Meteorological Society Annual Meeting in February of 2003. The papers include *Updating NOAA/NWS Rainfall Frequency Atlases*, which will give an overview of our approach, *Updated Precipitation Frequencies for the Semiarid Southwest United States*, which will present selected results from the Semiarid study, *Updated Precipitation Frequencies for the Ohio River Basin and Surrounding States*, which will present selected results from the Ohio study, and *NOAA/NWS Precipitation Frequency Data Server*, which will present the PFDS in detail.

6. Projected Schedule

The following list provides a tentative schedule with completion dates. Brief descriptions of tasks being worked on next quarter are also included in this section.

Data Collection and Quality Control [Complete]
Temporal Distributions of Extreme Rainfall [October 2002]
L-Moment Analysis/Frequency Distribution [October 2002]
Peer Review of Point Estimates [November 2002]
Spatial Interpolation [January 2003]
Precipitation Frequency Maps [February 2003]
Web Publication [March 2003]
Spatial Relations (Depth Area Duration Studies) [January 2003]

6.1 L-Moment Analysis

A comprehensive L-moment statistical analysis will be completed during the next quarter for all datasets through December 2000 for all durations and all regions. Partial duration series will be analyzed so that conversion factors from annual maximum series to partial duration series can be developed.

6.2 Spatial Interpolation

HDSC will deliver the point mean annual maxima (a.k.a. “index flood”) values to the Spatial Climate Analysis Service (SCAS) at Oregon State University. The SCAS will use PRISM to spatially interpolate the values to grids, which will later be used by HDSC to derive the precipitation frequency maps.

During the next quarter SCAS will prepare a first draft of the spatial interpolation.

6.3 Peer Review

The first review will be of the point precipitation frequency estimates. The second review will be of the spatially interpolated grids. The peer review of the point precipitation frequency estimates is scheduled to begin on and will conclude on. The review will include point frequency estimates and associated confidence intervals for all durations (5-minute to 60-day) and all return frequencies (2-year to 1000-year). It covers all stations, even those outside the core area that will be the focus of the Study. The purpose for the non-core area is to provide continuous data across the exterior study area border. Comments pertaining to data in non-core areas will be addressed according to their influence to the core study area.

The second review will be of spatially interpolated values.

6.2 Trend and Shift Analysis

The dataset will be analyzed for any trends or shifts in annual maxima through time. T-tests will be used to detect any linear trends in annual maxima or in variance, while t-tests, Mann-Whitney tests and Chi-squared tests will be used to determine any shifts in means of annual maxima. After completion of the trend and shift analysis, data quality control will be performed on stations exhibiting a significantly high linear trend and/or shift in the annual maxima time series data.

6.3 Temporal Distributions of Extreme Rainfall

Temporal distributions for storms of 4-day duration will be computed during the next progress period.

6.4 Spatial Relations (Depth Area Duration Study)

The method to be used for computing the DAD curves has been selected. Software to decode and format the data files and perform the DAD computations will be developed and run. If additional dense-area-networks are available, they will be added to the database.

References

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